

UVES-VLT High Resolution Spectroscopy of GRB080319B and GRB080330 Afterglows

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Abstract. We study here the Gamma-Ray Burst (GRB) environment through the analysis of the optical absorption features due to the gas surrounding the GRB. In particular, we analyze high resolution spectroscopic observations of GRB080319B and GRB080330 taken with UVES at the VLT, starting 8m30s and 1.5hr after the GRB trigger, respectively. The spectra show that the ISM of the GRB host galaxies are complex, with several components contributing to the host absorption system. In addition, we detect strong excited absorption lines, from which we derive information on the gas distance from the site of the GRB explosion. Under the assumption that the excited features are produced by indirect UV pumping, we found that this distance results to be 2-6 kpc for GRB080319B and 280 ± 50 pc for GRB080330, meaning that the power of the GRB radiation can influence the conditions of the interstellar medium up to a distance of several hundred pc.

Keywords: Gamma-ray Bursts, Inter-Stellar Medium, Atomic Processes

PACS: 98.70.Rz, 98.58.-w, 98.58.Bz

INTRODUCTION

For a few hours after their onset, Gamma Ray Bursts (GRBs) are the brightest beacons in the far Universe, offering a superb opportunity to investigate both GRB physics and high redshift galaxies. Early time spectroscopy of GRB afterglows can give us precious information on the kinematics, geometry, ionization and metallicity of the interstellar matter of GRB host galaxies up to a redshift z 4, and of intervening absorbers along the line of sight. High resolution spectroscopy is important for many reasons: (i) absorption lines can be separated into several components belonging to the same system; (ii) the metal column densities can be measured through a fit to the line profile for each component; (iii) fine structure and other excited lines can be resolved.

OBSERVATIONS

GRB080319B. This is the brightest GRB ever, visible worldwide and naked-eye in the first seconds. The afterglow has been observed from the very beginning of the event. UVES was on target 8m30s later, when the magnitude was $R=12$. This observation was followed by two more exposures 2 and 3 hours later (Fig. 1). We find five systems at $z=0.937$ (GRB host), 0.76, 0.71, 0.57 and 0.53.

GRB080330 afterglow was observed with UVES 1.6 hours after the trigger (Fig. 2). We find three main absorption systems at $z=1.51$ (GRB host), 1.02 and 0.82. The resolution of the spectra reaches 7.5 km/s in the observer frame. The S/N is 3-6 for GRB080330 and up to

50 in the first observation of GRB080319B.

ANALYSIS

The features were analysed using the line fitting program FITLYMAN, part of the MIDAS data reduction software package. FITLYMAN allows for the simultaneous fitting of multiple absorption/emission systems. For each absorption system several lines spread over the entire spectral range covered by the UVES observations were fitted together. The strongest absorption lines are observed in the host galaxy systems, which are the only ones considered in the following. Six and four components are necessary in order to obtain a satisfactory fit for the line profiles of the absorber at the redshift of GRB080319B and GRB080330, respectively (Fig. 3). Thus, as observed in previous high resolution spectroscopy of GRBs (Fiore et al. 2005, D'Elia et al. 2007, Piranomonte et al. 2008), the circumburst absorber shows evidence of a clumpy structure, consisting of multiple shells.

EXCITED LINES AND THEIR VARIABILITY

Fine structure lines and other excited features, belonging to the FeII, NiII and SiII levels have been identified in these GRBs. Excited lines can be produced both by collisional or radiative processes. Vreeswijk et al (2007), using multi-epoch high resolution spectroscopy, observed variability in the fine structure FeII lines of GRB060418, which is a clear signature of indirect UV pumping excit-

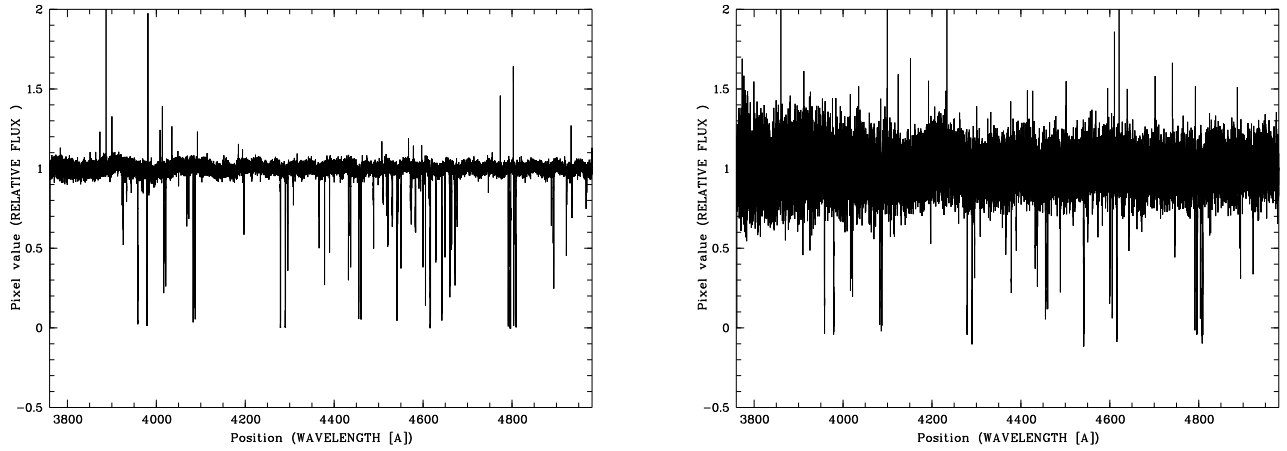


FIGURE 1. The high resolution spectrum of GRB080319B taken with UVES 8,5m (left) and 1.9hr (right) after the trigger.

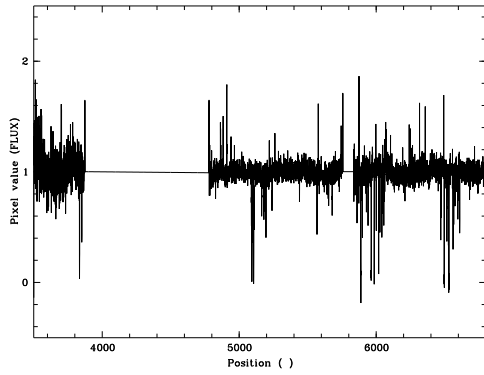


FIGURE 2. The high resolution spectrum of GRB080319B taken with UVES 8,5m (left) and 1.9hr (right) after the trigger.

ing such features. In other words, the decreasing UV flux coming from the GRB excites the higher FeII levels with lesser and lesser efficiency. An even stronger variability has been observed in GRB080319B, where a variation of a factor of 4-20 in the FeII excited lines have been detected in less than 1 hour rest frame, while the ground state lines remained almost constant (Fig. 3).

GAS DISTANCE FORM THE GRBS

Due to this strong variability in the excited features observed in GRB080319B, we can safely assume that UV pumping is the responsible for the production of these lines, and we can estimate the distance of the gas from the GRB explosion site. First of all, we can state that component 1 is the closest to the GRB, since it maintains a significant absorption from the excited levels even at later times (Figs. 4 and 5). A more quantitative

approach needs the comparison of the observed data with the results from a time dependent photo-excitation code. We built a code that computes the column densities of more than a hundred FeII levels as a function of an incoming UV flux decreasing with time. Once the lightcurve of GRB080319B has been used as input for this code, we can estimate the distance of the absorbers from GRB080319B (Fig. 5). We find that the gas of component I is 2 kpc away from the source, while that of component III is at 6 kpc. This is a surprising result, since it reveals a possible extragalactic origin of the gas clouds at the host galaxy redshift, and tells us that the powerful GRB/afterglow emission can fully ionize the intervening gas up to the kpc scale. Even if we do not have multi-epoch data for GRB080330, we can assume that UV pumping is at work also for this GRB in the production of the excited lines. Under this hypothesis, component IV results the closest to the GRB, since it is the only one featuring excited levels (Fig. 3). Moreover, we can compare again the results from the photoexcitation code with the observed column densities (Fig. 6). We find that for GRB080330 the distance of the closest absorber is 280 ± 50 pc, a smaller distance than in GRB080319B, possibly due to the weaker flux of this GRB.

CONCLUSIONS

The absorption spectra of GRB 080319B and 080330 confirm that the GRB afterglows are extremely complex, featuring several systems at different redshifts. The host galaxy systems are clumpy, and are constituted by 6 and 4 components, respectively. Such components can be separated only with high resolution spectroscopy, which is thus the only effective tool to allow for a detailed study of the GRB surrounding medium. Among the host galaxy

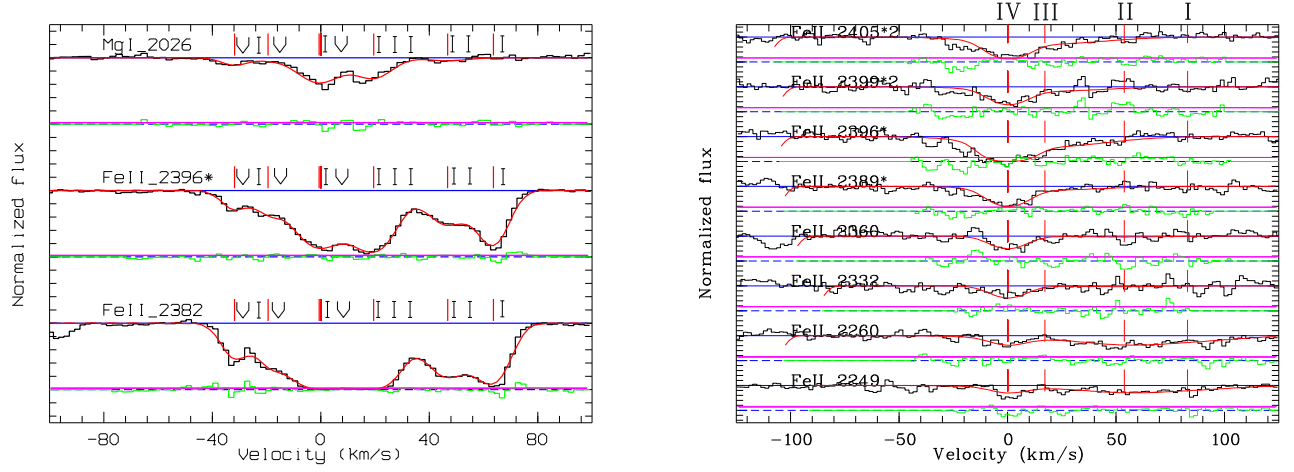


FIGURE 3. Left panel: the FeII 2382, FeII 2396* (fine structure) and MgI 2026 absorption lines in GRB080319B. Right panel: several ground (2249, 2260), fine structure (2389, 2396, 2399, 2405) and excited (2332, 2360) FeII lines in GRB080330. Six and four absorption components have been identified in the two GRB circumburst environment, respectively.

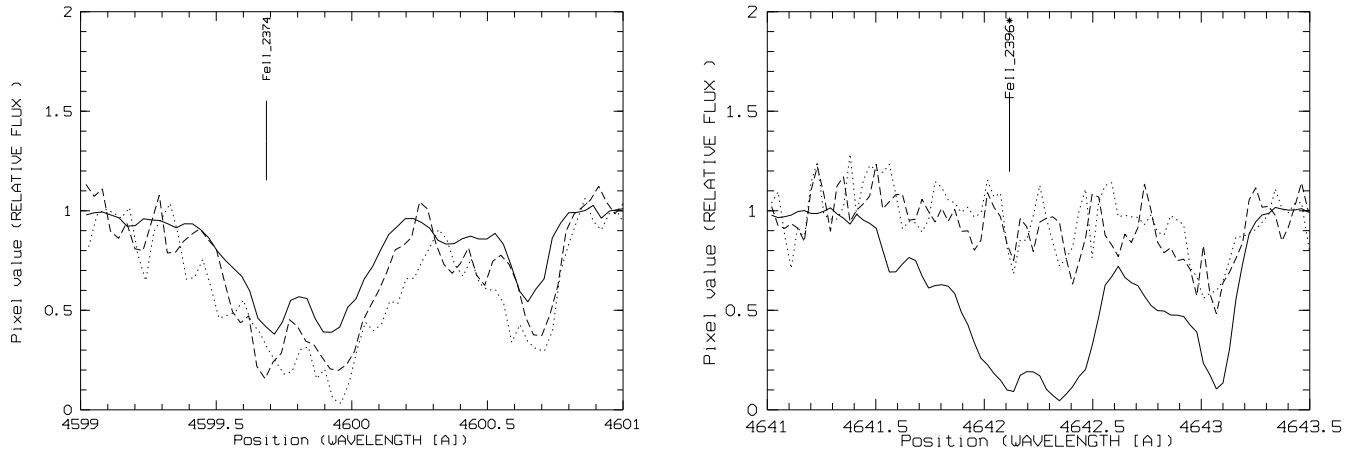


FIGURE 4. The FeII 2396 fine structure (left) and Fe II 2382 ground state (right) lines for GRB080319B. Solid, dashed and dotted lines represent the first, second and third UVES observation, respectively. Note the strong variation of the fine structure line while the ground state one is almost constant.

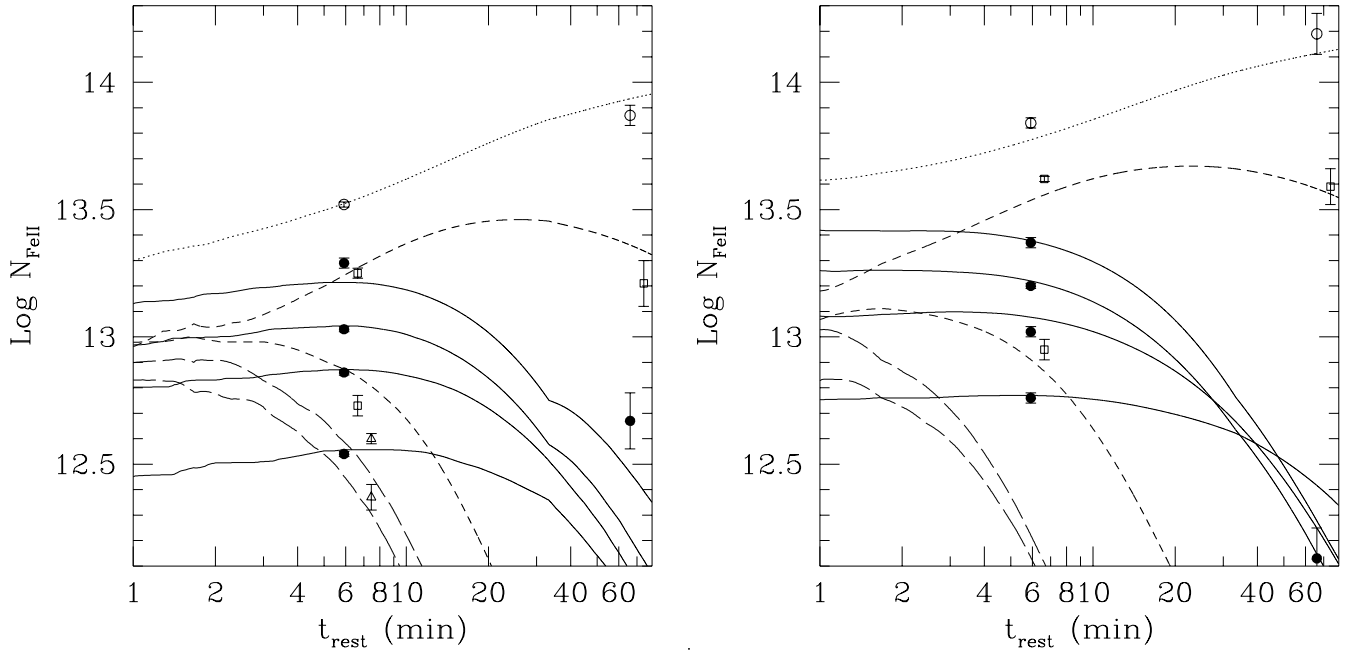


FIGURE 5. Comparison between the observed column densities in the FeII levels of GRB080319B and that predicted by our photo-excitation code. Left panel refers to component I, for which a distance of 2 kpc from the GRB is predicted. Right panel is for component III and a distance of 6 kpc is found.

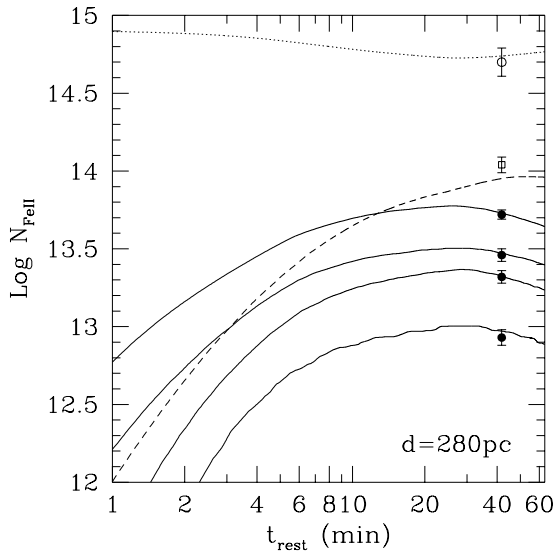


FIGURE 6. Comparison between the observed column densities in the FeII levels of GRB080330 and that predicted by our photo-excitation code for component IV. A distance of 280 ± 50 pc from the GRB is predicted.

absorption features, fine structure and other excited lines play a fundamental role. In particular, the strong variability observed for these features in GRB080319B al-

lows to conclude that their production mechanism is UV pumping. Moreover, the distance of the absorber from the GRB can be estimated by comparison with time-dependent photo-excitation codes, and the result is 2-6 kpc, i.e., the absorber can possibly have an extragalactic origin. Assuming also for GRB080330 that UV pumping is at work, we derive a distance of 280 ± 50 pc of the absorbing gas from this GRB. This is a considerably smaller distance, possibly due to the lower flux level of GRB080330. Nevertheless, it confirms that GRBs influence their environment up to distances of several pc.

More details on this work can be found in D'Elia et al (2009 a&b)

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